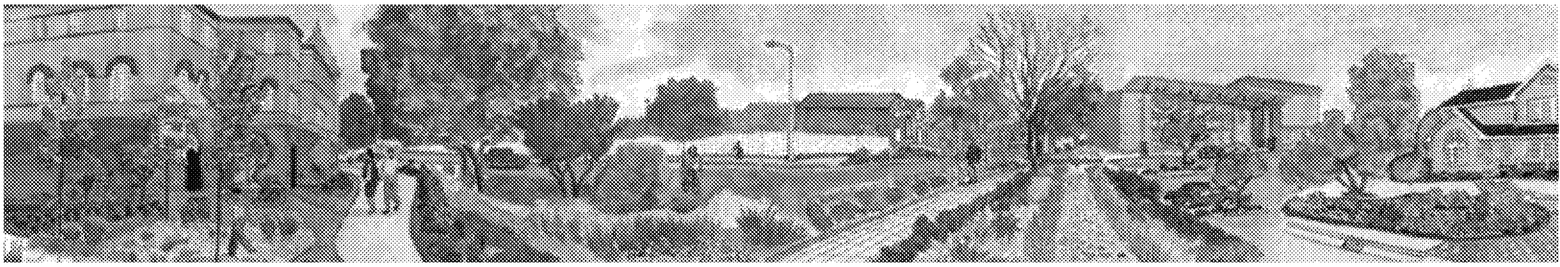

Strategy to Optimize Resource Management of Stormwater

Projects 1a Promote Stormwater Capture and Use and 1b Identify and Eliminate Barriers to Stormwater Capture and Use

Product 1–Final Report: Enhancing Urban Runoff Capture and Use
April 10, 2017

"Barriers are barriers if you allow them to be; but we can break through them with drive and perseverance" – Neal Shapiro, City of Santa Monica

STORMS
STORM WATER STRATEGY
CALIFORNIA WATER BOARDS

DIVISION OF WATER QUALITY
STATE WATER RESOURCES CONTROL BOARD

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Acronyms and Abbreviations

AASHTO	American Association of State Highway and Transportation Officials
ACP	Alternative Compliance Pathways
APA	American Planning Association
APWA	American Public Works Association
ARCSA	American Rainwater Catchment Systems Association
ASCE	American Society of Civil Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BMP	Best Management Practice
CASQA	California Stormwater Quality Association
CDFW	California Department of Fish and Wildlife
CDPH	California Department of Public Health
CEQA	California Environmental Quality Act
CWH	Council for Watershed Health
CWP	Center for Watershed Protection
DDW	Division of Drinking Water
DFA	Division of Financial Assistance
DWQ	Department of Water Quality
DWR	Department of Water Resources
EIFD	Enhanced Infrastructure Financing Districts
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
GSA	Groundwater Sustainability Agency
IRWMP	Integrated Regional Water Management Plan
ITRC	Interstate Technology Regulatory Council
JPA	Joint Powers Authority
LID	Low Impact Development
MS4	Municipal Separate Storm Sewer System
NACE	National Association of County Engineers
NACTO	National Association of City Transportation Officials
NAFSMA	National Association of Flood and Stormwater Management Agencies
NMSA	National Municipal Stormwater Alliance
NPDES	National Pollutant Discharge Elimination System
POTW	Publicly Owned Treatment Works
RHAA	Rainwater Harvesting Association of Australia
RAA	Reasonable Assurance Analysis
Regional Water Board	Regional Water Quality Control Board
ROW	Right of Way
SCM	Stormwater Control Measures
SGMA	Sustainable Groundwater Management Act
State Water Board	State Water Resources Control Board
STORMS	Strategy to Optimize Resource Management of Stormwater
SWRP	Storm Water Resource Plan
TMDL	Total Maximum Daily Load
TRB	Transportation Research Board
ULI	Urban Land Institute
Water Boards	State Water Resources Control Board and Regional Water Quality Control Boards
WEF	Water Environment Federation
WERF	Water Environment Research Foundation

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Executive Summary

Water conveyance and storage infrastructure moves water from areas of availability to areas of demands. These can include municipal, agricultural, and specific environmental uses. Water conveyance is highly time-dependent, being built to deliver water not only where, but also when, it is needed. In California, state and federal agencies built large-scale infrastructure systems for moving water from Northern and Eastern areas to municipal and agricultural users along the Coast and Central Valley (Hanak et al. 2011; Hundley 2001). Population growth and increasing water demands are driving many municipalities to invest in alternative sources of water supply beyond conveyance and imports. In particular, local capture and use of urban stormwater runoff is becoming a more attractive source as out-of-basin supply becomes less reliable and access becomes more competitive (LADWP 2016; Santa Monica 2014) . Costs of out-of-basin water supply (energy, delivery, environmental mitigation, etc.) are also increasing (MWD 2015), providing further motivation for better management of local water resources.

Consequently, capture and use has been focused on supporting water supply through either capture and tank storage for direct use or recharge of useable aquifers (NAS 2016). Because the State Water Resources Control Board (State Water Board) aims to support valuing stormwater as a resource and encouraging active capture of urban runoff, a definition of urban runoff capture and use was developed: the intentional collection of urban runoff to augment surface water supplies, to recharge groundwater, or to support ecosystems. This new, broader definition expands on the traditional view by recognizing ecosystems as a potential user of urban runoff. A primary objective of this report is to maximize the implementation of capture and use within a one water approach (U.S. Water Alliance 2016) by identifying projects to overcome barriers associated with justifying, funding, and administering capture and use projects.

The actions to overcome the barriers identified in this report will involve collaborative participation by public agencies, professional associations, and the general public. This report focuses on identifying key projects that will either provide incentives to implement capture and use projects or remove barriers that may prevent the implementation of such projects. Public agencies and professional organizations are identified in this report to either lead or advocate for certain projects. While public engagement will also be a critical component of implementing capture and use projects, this report develops concepts for future messaging efforts to emphasize the value of stormwater as a resource. The following sections summarize the findings, barriers, and potential advocates and partners identified within this report.

Summary of Barriers

There are a variety of barriers to stormwater capture and use and its implementation in California. The barriers listed in this report were identified by case studies as well as the experiences of the technical advisory committee (TAC). This section categorizes and summarizes these barriers. Additional information is included in Section 4 of this report.

Financing/Valuation

- Capture and use projects are often infeasible without augmentation from temporary funding sources.
- There is a lack of guidance to quantify all water and non-water benefits in a multiple benefit project to solicit additional funds.
- Transportation is a ubiquitous land use and the public right of way is the most common area to target for green infrastructure, however, integrating stormwater capture within transportation infrastructure can be challenging due to constraints on transportation funding.
- Stormwater infrastructure does not benefit from the same state and federal level of support provided to past water infrastructure investments (e.g., water supply and wastewater) and current state funding (e.g., Prop 1) is insufficient to cover proposed capture and use projects.

Education/Guidance

In this area, many tools, structures, and programs are lacking, including:

- Analysis tools for retrofit options on existing infrastructure including evaluation of potential water rights restrictions, particularly for flood control facilities.
- Outreach to increase understanding by the public and decision makers.
- Guidance on the design and applicability of new centralized capture and use systems.
- Guidance for designs specific to local conditions that account for soil types, instream flows, rainfall, climate, and demand.
- Guidance for storage limitations and treatment requirements for surface water long-term storage to avoid worsening water quality.
- Training on integrated water resource planning and the one water approach.
- Training on the appropriate scale and use of triple bottom line analyses to evaluate the social, economic, and environmental benefits of projects.
- Expansion of the Department of Water Resources (DWR) Water Management Planning Tool (through coordination between State Water Board staff and DWR) to incorporate stormwater infrastructure and analyze stormwater as a supply source.
- Guidance in the use of triple bottom line analysis to identify and evaluate the water source alternatives in the state's integrated watershed plans.

Institutional/Policy

- Varying municipal separate storm sewer system (MS4) permit post-construction requirements among Regional Water Quality Control Boards (Regional Water Boards) and the statewide NPDES permits makes creating statewide training programs and design guidelines for capture and use difficult.
- Stormwater conveyance systems may not be viable means to move stormwater to regional stormwater capture and use systems in cases where those conveyances have been determined to be "waters of the US" subject to receiving water limitations (RWL). If violations of RWL are probable, that would then require treatment to RWL standards prior to discharge to those conveyances, increasing treatment costs and possibly

requiring treatment systems or capture and use infrastructure in places that are not cost optimal.

- Lack of use points to a perceived regulatory barrier to implementation of drywell systems for capture and deep infiltration of stormwater in Northern California even though in Southern California there are many examples of drywells being implemented for this application.
- Inconsistent regulations for infiltration BMP siting and pretreatment requirements that are protective of groundwater resources in consideration of performance of different infiltrating practices such as drywells.
- Water districts, municipalities, and flood control agencies are not required to collaborate on water supply and capture and use projects and there are no mechanisms to share costs and cost-saving benefits. This can either make projects funded solely by stormwater funds cost prohibitive or preclude efficient placement of these facilities within the footprint typically under the control of stormwater agencies.
- There are no requirements to assess stormwater as a potential supply source in integrated regional water management plans (IRWMP) or municipal general plans. It is only recommended, but not required, to assess stormwater as a potential supply source in urban water management plans.
- Integration of water resources is not required; instead water resources (water supply, wastewater, recycled water, stormwater, and drainage) are integrated into developments independently.
- There are no requirements to analyze the environmental benefits and costs of urban runoff projects compared to other water sources, so capture and use systems are often undervalued.
- There is no requirement, and no uniform established methods, to assess the disruption to local watershed ecosystems and impact to groundwater due to excessive capture of stormwater and routing away from the area normally receiving the precipitation.
- There are no state-accepted treatment standards or technologies for direct, non-potable water use. (Ongoing work by the National Blue Ribbon Commission for Onsite Non-potable Water Systems will provide a basis for developing local and statewide standards.)

Technology

Technology was not reported as a limiting factor in the ability to implement capture and use projects in the case studies. However, innovative capture and use technologies can be better promoted for sites that constrain traditional approaches. For example, in high density development settings, innovative design for new buildings and roadways can promote integration of stormwater capture infrastructure with utilities and other infrastructure. Barriers to these approaches relate to policy, rather than technological capability.

Advocates and Partners

The public agencies and professional associations that may lead or advocate for certain projects to overcome the barriers listed in the previous section are identified where appropriate in the following sections. Additional information regarding the barriers, drivers, potential projects for statewide solutions, and lead agencies is included in Table 2. More information on additional resources identified in this report are found in Section 3.2.

Summary of Findings

These findings are meant to focus on how capture and use can be successful, despite the barriers identified in this report. These findings are also meant to inspire project proponents to implement capture and use and support projects that will eliminate barriers to maximize the likelihood of success for future capture and use projects. Additional information regarding the key findings of this study can be found in Section 5.

Motivating Change

Finding 1: Capture and use projects or BMPs that increase on-site runoff retention also reduce the effects and associated liability of discharging to local water bodies.

Finding 2: Public engagement is key to increasing BMP integration into other public and environmental objectives, which will increase the likelihood of robust, multiple-benefit, and cost-effective projects. Consistent and effective messaging is critical, according to the Project Advisory Group, and CASQA found that it requires specialized expertise and broad coordination (2017a).

Viable Urban Supply

Finding 3: Urban runoff can provide a sizeable source of water supply. In some parts of the state, stormwater runoff currently constitutes 10% or more of urban supplies.

Finding 4: Technological limitations were not reported in case studies. Instead, reported barriers relate to policy, finance, institutional structure, and awareness. Awareness of technological capabilities can overcome some perceived barriers. For example, space limitations and lack of permeability in near-surface soils are perceived barriers that can potentially be addressed by increased awareness of drywell technologies.

Finding 5: With California's highly variable climate and increasing urban demands, it is likely infeasible to meet all urban demands through stormwater capture alone. The scale of capture and use required to meet typical urban needs would necessitate volume storage that is many times greater than current stormwater management design storms. Additionally, because this volume of precipitation falls over a span of several storms throughout the year in most parts of the state, peak volume storage requirements would be extensive. Urban areas with underlying aquifers are better situated to capture and store water, as aquifers provide a cost-effective storage solution and a clearer path to overcoming existing storage barriers for capture and use. The city of the future should strive to use and reuse local water, including captured stormwater.

Better Information Needed

Finding 6: In most parts of the state, using urban runoff as a water supply is more expensive than utilizing existing sources. Distributed stormwater capture, which is easier to implement in dense urban areas, is more expensive, while larger centralized stormwater capture requires substantial tracts of land that can be hard to site in built-out areas. But, current water rates often do not accurately reflect full water supply costs. Existing water supply infrastructure was built and paid for in part decades ago, while environmental regulations and water scarcity are increasing current costs.

Improved rate-setting procedures in water districts could allow for better comparisons of existing and new infrastructure cost estimates. Water districts can contribute to proper valuation by using rate setting techniques that consider factors such as the environmental costs associated with different water sources and the cost increases associated with likely climate change scenarios. Water districts typically set standards based on a 5-year future projection, fundamentally limiting their ability to make investments in alternative water sources based on longer term changes (City of Vallejo 2016; LADWP 2016).

Finding 7: Standardized procedures or decision support tools do not exist for stormwater capture and use planning. Several major stormwater planning applications now include modules to support LID and BMP implementation, but cost and performance data is dispersed and few studies have effectively considered the potential for stormwater capture to comprise a significant source of urban water supply. Capture and use approaches are typically more expensive than upgrading existing grey infrastructure when comparing new vs. marginal cost increases, and when failing to include benefits and costs for environmental and social aspects of system management. Improving valuation of capture and use—both economic and non-economic—can increase community and political support, helping overcome financial and institutional barriers. Proper valuation of multiple-benefit projects will also make capture and use projects more attractive for various funding sources (e.g., transportation). Decision support tools can assist in optimizing new system designs with green and grey infrastructure that better promote sustainable and holistic water management, exemplified by one water approaches being pursued in some areas of the state.

Finding 8: Stormwater infrastructure can support multiple objectives, but these must be considered at the design stage. Centralized strategies better achieve multiple benefits when agencies charged with managing different types of natural resources collaborate to meet resource objectives (e.g., water supply, flood control, habitat, air quality, and receiving water protection). Decentralized strategies tend to be implemented within land uses that are primarily dedicated to other infrastructure (e.g., transportation) so choosing approaches that also support that infrastructure will be critical in marshalling funding designated for that infrastructure.

Finding 9: There are thousands of stormwater control measures (e.g., flood control facilities and stormwater detention basins) in California, so retrofitting or modifying existing regional facilities is a promising strategy to substantially increase capture and use. Resolving the uncertainty regarding existing water rights diversions and capture and use may encourage small scale retrofits where the cost of investigating rights is high compared to the benefit derived from the project. Central repositories for regional data on BMP, LID, and capture and use performance and costs would support better planning processes. In particular, databases for runoff and flood infrastructure— currently housed in more than 1,000 different flood control agencies statewide—could be brought together in regional databases in support of opening access to information that allows for better assessments of benefits (DWR 2013).

Tradeoffs and Consequences

Finding 10: Developing appropriate targets for capture and use requires considering the complex tradeoffs between benefits and potential unintended consequences, such as negative groundwater quality impacts. Also, existing ecosystems may have become dependent on current urban runoff flow regimes, so changing those flows will impact those ecosystems. A framework for valuing the support of different ecosystems would help further evaluate the effects of capture and use.

Hybrid Strategies

Finding 11: Future urban water management will require a mix of green and grey infrastructure. Costs, technologies, and social views are driving this trend toward hybrid systems. For stormwater, this means designing systems that use distributed infrastructure to capture and attenuate runoff throughout the landscape, coupled with key larger municipal infrastructure that assures performance. But best practices for design and management are unclear and risks are still significant. For instance, decentralized capture and use strategies on private land may not be well maintained over time. Alternatively, investing in large infrastructure is expensive and may not directly achieve receiving water requirements or estimates of groundwater recharge, stifling additional investments (Sedlak 2014; NAS 2016; Porse 2013).

Finding 12: Applying fit-for-purpose standards to the different uses of urban runoff may reduce unnecessary treatment costs. For example, risk-based treatment standards applied to harvested water for protection of public health based on likely exposure may result in decreased costs of direct use systems (SFPUC 2014).

Promising Actions

Potential projects are identified in Section 4.5. Projects that are recommended (immediately actionable) are included in Section 5.2 and touch on the following topics:

Local Actions

1. Collect data necessary for asset management and justification for stormwater fees. Develop costs for agreed-upon customer and environmental water resource service levels while minimizing life cycle costs (CASQA Actions 2.7 and 2.8).
2. Update municipal general plans to require consideration of stormwater as a water supply source (CASQA Action 1.1).
3. Align or leverage water services (e.g., water supply, flooding) with capture and use to the benefit of both (e.g., Hansen Spreading Grounds).
4. Use alternatives analysis tools to engage stakeholders and develop support for water infrastructure that delivers social, economic, and environmental benefits (CASQA Action 2.5).
5. Capture and use project advocates (e.g., water districts and MS4 programs) coordinate with local and state transportation authorities to look for opportunities for shared projects and benefits. (e.g., Elmer Avenue Stormwater Capture Project; CASQA Action 3.1).

State Actions

1. Explore options for funding stormwater capture and use (Projects 4A and 4B as well as CASQA Action 2.7).

2. Improve consideration of urban runoff in IRWMPs (CASQA Action 1.1).

3. Resolve the policy questions regarding use of promising technologies and approaches.
    a. Resolve regulatory and policy issues related to the use of drywells for stormwater management and clarify the minimum standards that local enforcement agencies would consider for local policy development (State Water Board).
    b. Update Integrated Regional Watershed Management (IRWM) guidelines and online tools to consider local urban runoff as a potential source (DWR).
    c. Improve land use codes governing building footprints to adopt performance standards for new development and redevelopment to support decentralized capture and use technologies, such as LID (municipalities).
    d. Establish a framework to assess local ecological impacts, positive and negative, to capture and use diversions (DFW, State Water Board).

4. Expand/improve regulatory performance measurements to reflect capture and use objectives (State Water Board).
    a. Develop/align post-construction stormwater control requirements for capture and use objectives based on factors such as watershed processes, public use needs, and ecologic value of current flow regimes.

5. Identify the most effective and feasible capture and use strategies.
    a. Evaluate the regional and statewide opportunity to retrofit conventional detention basins to enhance capture and use. The number, location, and volume of stormwater/flood control basins are a prime opportunity for significant benefit (DWR or provide funding to local flood and stormwater agencies).
    b. Establish design guidelines for public projects reflective of capture and use goals.

1 Introduction

Through this first-phase project, the State Water Resources Control Board (State Water Board) is laying a foundation of understanding on which to create and enhance incentives for implementing urban stormwater[1] runoff capture and use including:

- Developing a consensus definition of stormwater capture and use (Section 3)
- Evaluating technical approaches for stormwater capture (Section 3 & Appendix A)
- Identifying opportunities and barriers to stormwater capture and use, including legal, regulatory, technical, behavioral, fiscal, and policy areas, as well as actions that can be taken by the State Water Board and Regional Water Resources Control Boards (Regional Water Boards) to facilitate implementation of capture and use (Section 4)
- Identifying hydraulic and watershed-based methods to develop capture and use targets that can be used for site-specific sizing of capture infrastructure (See "Barriers Analysis" in Section 4)
- Identifying case studies that illustrate successful implementation of capture and use (Appendices B and C)

A primary purpose of this report is to maximize the implementation of capture and use within a "one water" approach by identifying projects to overcome barriers associated with proposing, funding, and administering capture and use projects. Embracing a "one water" approach focuses on promoting multiple benefits associated with capture and use such as protecting water quality and attenuating flood flows.

California has spatial and temporal distribution of precipitation that often do not align with water demand. Currently, water conveyance infrastructure, including canals, aqueducts, and rivers and streams, moves water from areas of greater availability to areas of greater scarcity, helping meet water demands for agriculture, industry, and municipalities (Hanak et al. 2011; Hundley 2001) throughout the state. Also, peak water demand for municipal and agricultural uses occurs during summer months when there is little precipitation. Water infrastructure moves captured runoff and snowmelt to meet those seasonal demands (DWR 2013). As demand grows and water imports from out-of-basin sources become less reliable, local urban stormwater capture and use will become more attractive as a source of water. Monetary costs of imported water supply—including the acquisition and movement of water along with associated energy requirements—are increasing (MWD 2015), further motivating better management of local water resources. Reducing imports can have additional benefits of retaining or restoring aquatic habitat and reducing greenhouse gas emissions with lower energy requirements.

California has three main resources for water storage: surface water impoundments, snowpack, and aquifers. When year-to-year surface water availability from impounds and snowpack decreases, use of aquifers increases. Groundwater is less susceptible to short-term drought,

[1] In this report, the term urban stormwater runoff is inclusive of rainwater, as defined in the Rainwater Capture Act of 2012 as "precipitation on any public or private parcel that has not entered an offsite storm drain system or channel, a flood control channel, or any other stream channel and not previously been put to beneficial use" (Wat. Code, § 10573). Some jurisdictions differentiate stormwater and rainwater (SFPUC 2014).

but some aquifers are in critical overdraft in much of the state (CNRA 2016) and during drought periods the consumption of groundwater is much higher (Xiao 2017).

Why Urban?

In the West, the infrastructure for rural runoff capture for transport to regions of need is well-developed, often due to massive investment at federal, state, and local levels. In contrast, local use of urban runoff has not reached its full potential. To address this potential, this project focuses on urban runoff capture.

Why Runoff?

Not all water that flows from the urban environment is stormwater. In many cases, anthropogenic dry weather flows can provide a substantial amount of water. To consider as many potentially valuable sources of water as possible, all urban runoff is included in this project, not just stormwater runoff.

Throughout Western North America, water sources are becoming further stressed. For instance, the Colorado River, which supports agricultural and municipal uses across seven states and Mexico, is over-allocated (Meyer 1966). A similar story is occurring for many water resources throughout the arid west, stemming from increased requirements for in-stream environmental water needs, highly cyclical climates with droughts that are expected to increase in intensity, and reduced snowpack. As municipalities look to plan for future water needs and growth, urban stormwater runoff may provide one option to address water resource challenges faced in California.

Stormwater can be captured and stored using a variety of methods. Stormwater capture can be accomplished by implementing best management practices (BMPs) that include green roofs, infiltration basins, detention basins, and bioretention raingardens. Captured stormwater can be stored for use on site using underground tanks and reservoirs or used to recharge groundwater. Use of stormwater to recharge groundwater is particularly attractive because aquifers are not as volume-limited as surface reservoirs (Lund et al. 2016). Further, groundwater extraction is not constrained by flood storage obligations and other rules that affect surface water reservoir operations, though groundwater extraction can be constrained by pumping rates, depletion cones, and temperature[2] management objectives for in-stream flows (Langridge et al. 2016). Another clear advantage of groundwater storage is that water can usually be claimed immediately without time limitation due to the higher storage capacity of aquifers and lack of constraints associated with flood storage obligations.

Stormwater capture can also support aquatic habitat preservation and restoration by reducing peak flows and volumes generated from impervious surfaces, yielding urban hydrographs that more closely resemble less-disturbed watersheds (Hollis 1975). To protect water quality,

[2] Overpumping groundwater dewaters streams which reduces flows resulting in increased stream temperatures (North Coast Regional Water Board 2015).

treatment may also be a component of hybrid systems that treat and release stormwater to surface waters.

1.1 Goals

This project supports the overall mission of the State Water Board's Stormwater Strategy: to value stormwater as a resource. The goal of this project is to increase incentives for capture and use by identifying and proposing solutions to common barriers. The project concept is presented in the Strategy to Optimize Resource Management of Storm Water (STORMS) as Projects 1a and 1b. Follow up work is anticipated, as described in STORMS (State Water Board 2016). This project will help identify and refine some of that follow up work.

1.2 Objectives: Identifying Barriers, Constraints, and Incentives

A key step in identifying promising actions is analyzing impediments to capture and use projects. This must differentiate between constraints, the intrinsic realities limiting benefits and driving costs, and barriers that introduce inefficiencies in project delivery. Barriers, which result from a lack of knowledge or tools, institutional impediments (rules and jurisdictions), and public priorities, are the focus of this assessment.

Constraints strictly govern the design of a project and cannot be removed. Rainfall quantity and timing is a fundamental constraint of capture and use that cannot be manipulated (cloud-seeding aside). Other constraints that can influence project feasibility and drive costs or limit benefits include topography, geology, groundwater quality, existing water demand, proximity to water demand, timing of water demand, water rights, and the low cost of competing water sources.

Barriers, however, are problems that can be solved. In contemporary practice, solutions are often case-by-case or short-term. The resulting inefficiencies can drive up costs or dampen enthusiasm for progressive stormwater planning, yielding capture and use projects that fail to move beyond the initial planning stages. This project seeks to identify long-term solutions to these barriers for regions throughout California. Most barriers are based on unknowns and can be related to a constraint. For example, not knowing underlying geology is a technical barrier to developing a design. The solution is a site investigation. The result is quantification of the constraint—that is, the limitations of the geology to infiltrate and store water. Unknowns can be technical, financial, institutional, and even political or social. Barriers are the focus of this report. This report will also suggest the entities best poised to take action to address these barriers.

The underlying reasons for barriers are broad and complex. They reflect our past perspective of stormwater as waste rather than a resource. Perceived barriers often pose the most difficult barriers to mitigate or remove. While education may be sufficient to overcome some barriers of perception, local regulation, statewide policy, and even legislation may be necessary to overcome other perceived barriers to increase the level of comfort in implementing capture and use. Other barriers require improvements to our institutional structure, financial strategies, technologies, scientific knowledge, and regulations.

In addition to identifying barriers, this project also identifies incentives. Absent consistently available financial incentives, the primary strategy to increase incentives within this project is to identify ways to make planning, funding, permitting, and designing capture and use easier to implement and justify. The State Water Board has a separate STORMS project addressing funding.

1.3 Collaborative Approach

The State Water Resources Control Board and Regional Water Quality Control Boards (Water Boards) convened a Project Advisory Group (PAG) to provide input on the definition of capture and use and to inform the project team of the state of capture and use practices. The PAG was a volunteer group composed of the following entities:

- Department of Water Resources
- Los Angeles Department of Water and Power
- Los Angeles County Public Works
- Santa Clara Valley Urban Runoff Pollution Prevention Program
- AMEC Foster Wheeler
- Council for Watershed Health
- Environmental Protection Agency, Region 9
- California Stormwater Quality Association (CASQA)
- Torrent Resources
- UC Santa Cruz

Input and direction was also provided by the STORMS Core Implementation Committee, which is composed of the following entities:

- California Association of Sanitary Agencies
- California CoastKeeper Alliance
- California Council for Environmental and Economic Balance
- CASQA
- Association of California Water Agencies

The PAG met on October 17, 2016, to review the proposed capture and use definition, provide input on barriers, and to provide case studies that help identify possible solutions to capture and use barriers. That meeting resulted in the drafting of this report. The PAG met again on September 19, 2017, to review and comment on the key findings, barriers, and potential projects.

The Project Team, with Chris Beegan of the State Water Board as the project manager, included the following personnel:

- Brian Currier, Office of Water Programs at California State University, Sacramento
- Daniel Apt*, Olaunu Consulting
- Dominic Roques, Central Coast Regional Water Quality Control Board
- Dr. David Feldman*, University of California, Irvine
- Dr. Darla Ingles*, Low Impact Development Initiative
- Dr. Eric Stein*, Southern California Coastal Water Research Project

*Technical Advisory Committee (TAC) members

1.4 Report Organization

Section 2 of this report provides background on the evolution of stormwater infrastructure and management strategies. Section 3 presents the definition of capture and use as well as the goals of this phase of the ongoing effort by the State Water Board to encourage capture and use. Section 4 contains a discussion of current barriers, drivers, and factors affecting success. Section 5 summarizes key findings and corresponding constraints and barriers. It also suggests the most promising actions to increase capture and use based on impact and likelihood of success.

2 Background: Evolution of Infrastructure and the New Paradigm

To provide background for the identification and exploration of barriers, this section provides a review of stormwater management history and current practices, including a review of the types of public entities that have roles in water management.

2.1 California Stormwater Infrastructure and Changing Management Strategies

Most urban stormwater infrastructure in California is separated from sanitary sewer systems. Separated sewers are advantageous because they do not contribute to combined sewer overflows, where sewage can be released directly to watersheds during large storm events. However, many separate municipal stormwater systems were built with little or no water quality treatment until the advent of municipal separate storm sewer system (MS4) permits.

MS4s also have a legacy of moving stormwater to receiving waters as fast as possible. Before the onset of stormwater permitting, urban stormwater runoff was largely managed through flood control conveyance. First-order flood conveyance infrastructure—curbs, gutters, and drain inlets—was designed to drain flows quickly, preventing the collection of flood waters on urban roads and landscapes. Higher-order (downstream) conveyance infrastructure typically used storage in tanks and basins to attenuate flows, reducing the likelihood of exceeding the capacity of downstream conveyance. Channelized streams and rivers that moved the runoff were often constrained with walls or levees to protect adjacent properties. Generally, flood control systems were not designed for reduction of pollutants (NRC 2008).

The legacy of moving stormwater as quickly as possible also led to negative effects associated with hydromodification. Hydromodification occurs when urban runoff induces physical changes to local watersheds, landscapes, and surface drainage. Urban development is often associated with hydromodification (Stein et al. 2012). Modifications to land surfaces and runoff channels causes increases in surface runoff volume and rates. In particular, increased impervious surface cover, removal of topsoil and vegetation, and compaction of soils increases the amount of flow from a given amount of rain because the original shallow infiltration and retention of rainfall in soils is reduced (Miller et al. 2014). Impervious surfaces also increase the velocity of runoff by decreasing surface roughness, which increases the mobilization of pollutants (Pitt 1987). Dry weather stream flows can increase due to perennial discharge of wastewater effluent and nutrient runoff and/or groundwater seepage from leaks in subterranean drinking water supply and sewage collection pipelines (Townsend-Small 2013).

Adding impervious surfaces has four negative effects. First, increased flow velocities increase mobilization of pollutants on the land surface. Second, increased volume increases the erosive, channel-forming flows on downstream habitats (NRC 2008). Third, imperviousness decreases shallow infiltration and interflow to streams. Finally, impervious surfaces convey the many pollutants that comprise daily urban life.

Flood flow attenuation through retention can provide partial mitigation of hydromodification effects, but generally urban development produces a net increase in the magnitude and duration of critical, channel-forming flows on natural downstream systems that cannot be mitigated by traditional flood control infrastructure. Certain water quality BMPs, with some sizing modifications, have the ability to completely mitigate hydromodification (Stein et al. 2012). Current permits (e.g., NPDES Phase II) contain such requirements, but complying with typical hydromodification requirements can still result in a disruption in the water balance from the historic condition by allowing management practices to release water below channel-forming flows. The period of discharge can be greatly extended, so even after mitigating hydromodification effects, downstream wetland and aquatic habitats can still be affected.

Stormwater was commonly viewed and treated as a nuisance or danger. Managing it meant fast removal. A host of research through the 1980s and 1990s, however, began identifying the detrimental effects of stormwater runoff on local watersheds and aquatic habitat. In response, the National Pollutant Discharge Elimination System (NPDES) Phase I stormwater rulemaking evolved, and MS4 permits soon required pollutant reduction via stormwater treatment best management practices (BMPs) for new and redeveloping areas (USEPA 1991). The ultimate goal of BMPs was preventing exceedance of water quality standards that resulted, at least in part, from urban runoff. So urban runoff, which was previously viewed as physically destructive during large flows, was now additionally viewed as harmful during periods of low flows. The challenge for stormwater management became improving the quality of water and continuing to achieve flood protection goals.

While the majority of stormwater systems in California were designed simply to remove runoff, there are several notable exceptions that incorporate aspects of capture and use. For instance, the Fresno Metropolitan Flood Control District (FMFCD) made a concerted effort to build a flood control system in the 1960s focused on groundwater recharge and recreational benefits for both upstream flows and urban runoff (FMFCD 2016). In Los Angeles County, regional agencies have captured runoff to recharge local groundwater basins for decades. The Los Angeles Department of Public Works today operates a large system of interlinked upstream dams, channels, and spreading grounds across several watersheds, which can be used to divert flows from upper watersheds into a network of 25 spreading grounds in support of groundwater recharge (County of Los Angeles Department of Public Works 2006). The Irvine Ranch Water District (IRWD) also benefits from capture and use by diverting low-flow natural and urban runoff, as well as smaller storm flows, into its natural treatment system (NTS) of constructed wetlands throughout the San Diego Creek Watershed. In these wetlands, contaminants are removed and prevented from reaching Upper Newport Bay (IRWD 2012). And, the Orange County Water District (OCWD) has conducted stormwater capture for decades. Flows from the Santa Ana River, for example, are captured behind Prado Dam, the primary flood control facility along the river, via the Prado Wetlands, a specially-constructed wetland area that naturally removes nitrates and other contaminants for subsequent percolation into the groundwater basin (OCWD).

As a result of stormwater permits, new developments began to employ multiple-use basins for treating runoff and achieving flood flow attenuation. Post-construction requirements included low impact development (LID), but capture and use is often not prioritized or even recognized as an objective. This likely stems from the origins of LID as a method for older and often East Coast cities with combined sewers to meet stormwater permit requirements in the context of wet weather hydrology. As such, considerations like groundwater recharge were not the elements of primary concern. Capture and use has emerged in California as a result of the need for water supply, especially in downstream cities. Requirements for meeting Total Maximum Daily Loads (TMDL) as well as emerging alternative compliance pathways for meeting receiving water limitations (State Water Board 2015c) may steer permittees to meet MS4 requirements through on-site retention, which prevents discharges that would otherwise have to comply with receiving water limitations. Notably some localities such as the City of Los Angeles already require on-site retention up to a design storm. With most of these examples of capture and use, reducing the volume of urban runoff discharged to receiving waters is the primary mechanism by which water quality benefits are achieved. Because this reduction in volume is intrinsic to any capture and use strategy, capture and use is inherently beneficial to water quality in surface waters.

2.2 Valuing Stormwater as a Resource

The stormwater control measures, which are now primarily used for flood control, treatment, and hydromodification, have potential to achieve widespread capture and use of runoff. Doing so requires valuing stormwater as a resource. This movement is building. For instance, in 2008, the National Research Council outlined strategies for considering stormwater as a resource for water supply and recreational functions (NRC 2008). The California Water Boards have also recognized the importance of treating stormwater as a valuable resource where capture and use can result in multiple benefits within a watershed (California Water Boards 2016). This shift in perspective is also promoted in the California Stormwater Quality Association (CASQA) Strategic Plan (2010) and the CASQA vision statement (2017). These documents outline strategies to "Manage stormwater as a vital component of California's water resources in a sustainable manner, to support human and ecological needs, to protect water quality, and to restore our waterways." The original intent of LID involves valuing both stormwater and natural systems as resources that can work together to protect stream ecosystems by mimicking the pre-urban hydrologic model, with an emphasis on replicating the volume balance of runoff, infiltration, and evapotranspiration in urban catchments (Walsh et al. 2016).

Designing stormwater infrastructure to directly support ecosystems broadens the traditional approach to stormwater management. In this broader sense, retained stormwater can be put into soil where soil biota, macrophytes, and stream interflow systems improve water quality and ecosystems supported by baseflow or high groundwater. Ecosystem benefits include habitat improvement, increased food sources, carbon sequestration, pollutant uptake, reduced ozone (Nowak 2006), and reduced heat-island effects from plant growth. Improved baseflow results in decreased water temperatures and prolonged dry weather flows, and increased amounts and types of soil biota will aid in carbon sequestration and pollutant uptake (Klaus 2015).

Local stormwater capture can also lead to energy-saving schemes that (1) capture water before it becomes contaminated with the pollutants on streets and in sewers; (2) rely on energy efficient processes for removing contaminants; (3) treat water only to the extent necessary for intended use (fit-for-purpose water); and (4) obviate the need for diversion and large, centralized, energy-intensive treatment and distribution approaches. Stormwater capture and use can provide numerous co-benefits such as water quality improvement, green space, recreation and aesthetic value, wildlife habitat and corridors, carbon sequestration, pollination services, urban heat island cooling, increased property values, and improved public health and safety, as well as a much-needed supply of non-potable (fit-for-purpose) water in drought-prone areas (Brown 2009). See Appendix A for additional discussion regarding centralized and decentralized stormwater control measures (SCMs) and potential uses and ancillary benefits.

Stormwater capture can also reduce reliance on imported water from distant sources, which reduces inter-basin (or inter-region) transfers and polluted runoff. Stormwater supports the fit-for-purpose water supply concept by satisfying less sensitive water demands, such as certain household, landscaping, and commercial needs, with mildly polluted water. In a complimentary fashion, various grades of wastewater, which must be treated to a higher standard for reuse, can supply more sensitive uses. Finally, runoff from roads and driveways can be captured and harvested locally using distributed hybrid systems (for example, bioretention with an underdrain that feeds a cistern used for irrigation) configured to provide non-potable water for human use. The compilation of stormwater uses may also vary substantially among regions depending on climate, topography, geology, ecology, and human demands, and understanding these differences is critical to protecting surface waters (Walsh et al. 2016).

The National Academy of Science (2016) recognizes that urban runoff can be a part of the water supply portfolio even in areas like the arid southwest where meeting outdoor water demand was identified as a mismatch with rainfall seasonality. This report also evaluates using graywater to enhance local water supplies and promotes thinking in terms of complete watersheds (upstream and downstream cities). Similarly, the one water concept as described in the *Blueprint for OneWater* by the Water Research Foundation (WRF) fully embraces stormwater as a resource and provides a place where all sources of water can be evaluated for their optimal place to achieve economic, environmental, and social benefits (Paulson 2017; U.S. Water Alliance 2016). This new paradigm extends beyond stormwater and envisions an interconnected system that optimizes the tools of treatment, conservation, and recycling (Novotny 2010; Sedlak 2014).

In *The Water-Sustainable City*, Feldman (2017) acknowledges several advancements in Australia that are worth tracking and using as a basis for future work in California. A few observations on Australian experiences are:

- The lessons from Australian cities (e.g., Melbourne) are applicable to some California cities due to similar climate and limited groundwater resources.
- Treated stormwater is being studied as a drinking water source in Australia (McArdle et al. 2011)

Even as the benefits of stormwater capture are intuitive and widely supported by the new paradigm, barriers that are impeding the development, permitting, design, and funding of capture and use projects will have to be addressed to realize the benefits of capture and use. Some barriers, such as market pricing, will require collaboration well beyond the traditional stormwater industry, underscoring the importance of advocating for stormwater and urban runoff in particular as an important component of the development of a diversified water portfolio in California.

2.3 Crafting Agency Partnerships for Managing Stormwater as a Resource

Urban water management in California, like many municipal functions, is highly fragmented (Ostrom 1961; Ostrom 1962). A diversity of organizations, including municipal utilities, investor-owned utilities regulated by state agencies, private non-profit water companies, special purpose districts, and county districts, all provide aspects of urban water services. These organizations have funding sources that vary by duty and geography, but common funding sources are special taxes, utility fees, and bonds. Assembling projects and funding streams in this highly complex environment is a constant challenge for integrative water management in California.

Overlapping and disjointed missions are in part a result of diverging national laws and practices regarding water supply and quality that have origins in how, historically, governments came to manage water (Feldman 2017). Additionally, water supply, flood control, and wastewater infrastructure evolved in different time periods, so the entities charged with these functions were usually different (Tarr 1984; Melosi 2011). The separation of these authorities can lead to cost analysis that does not consider the total benefits that could be realized if all services were considered together. Non-government organizations and watershed groups should also be identified for project collaboration. EPA's "Surf Your Watershed" can be used to identify citizen-based groups within a particular watershed (https://cfpub.epa.gov/surf/locate/index.cfm). Institutional barriers to collaboration among public services will be explored later in this report. Figure 1 provides an example of a water supply system that integrates stormwater into surface water supply resource instead of discharging directly to the river. While this is theoretically possible, it would require a re-evaluation of operating permits (CA HSC 116550) in order to allow stormwater capture as source water for a water treatment plant.

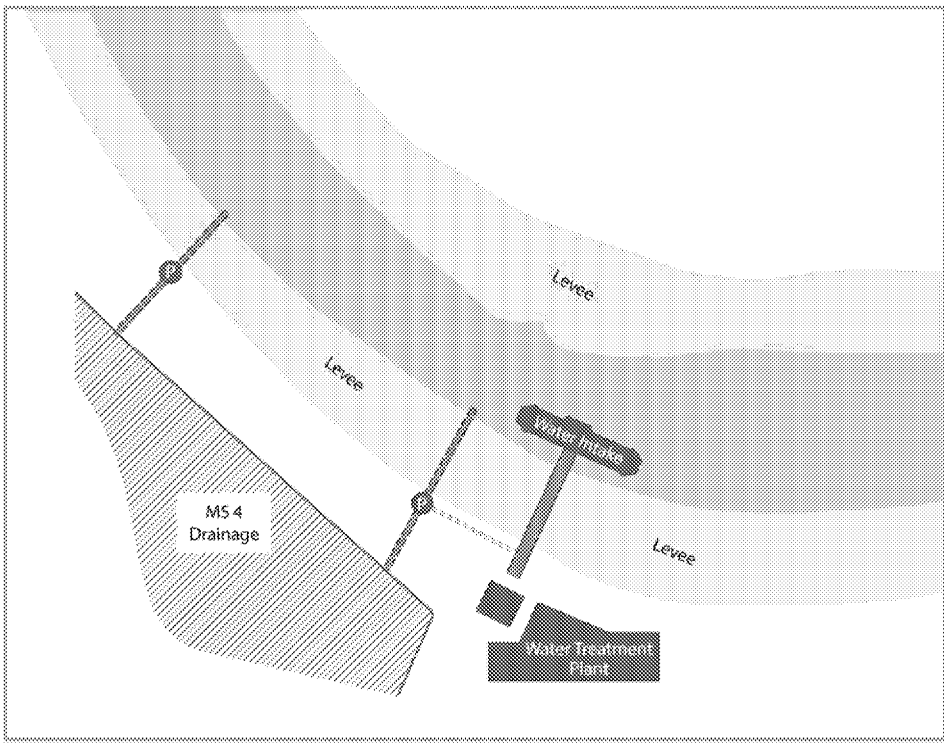

Figure 1: Stormwater Pump Station with a Traditional High-Flow Outlet to the Receiving Water and a Low-Flow Diversion to a Municipal Water Supply Treatment Plant

In addition, other municipal agencies outside of the water sector can contribute to stormwater management. For example, transportation may be the most important companion infrastructure for runoff management because transportation infrastructure footprints often overlay or directly contribute to stormwater drainage infrastructure. Energy and communications infrastructure also hold relatively untapped potential for multiple-benefit projects, though this is the one area where substantial technological questions must still be addressed, such as integration of stormwater capture infrastructure with other utilities and new infrastructure as discussed in later sections. Many of the case studies explored later in this report take advantage of park and recreation facilities. Figure 2 illustrates a park facility that captures stormwater from an industrial area and uses that runoff for irrigation purposes. An infiltration basin is also shown capturing runoff from a nearby neighborhood to promote groundwater recharge. Figure 3 illustrates shared infrastructure with transportation, buildings, and utilities.

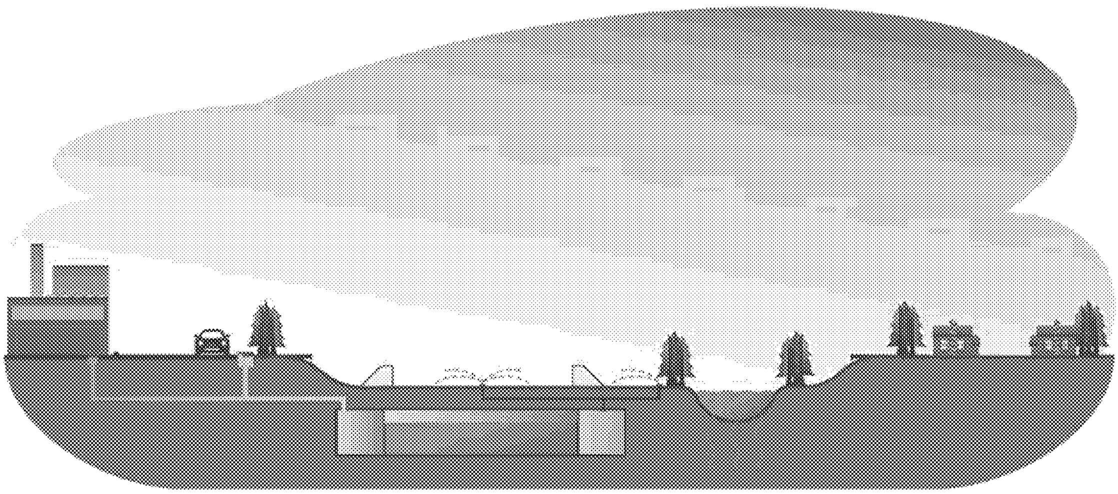

Figure 2: Parks and Recreation Capture and Use Facility

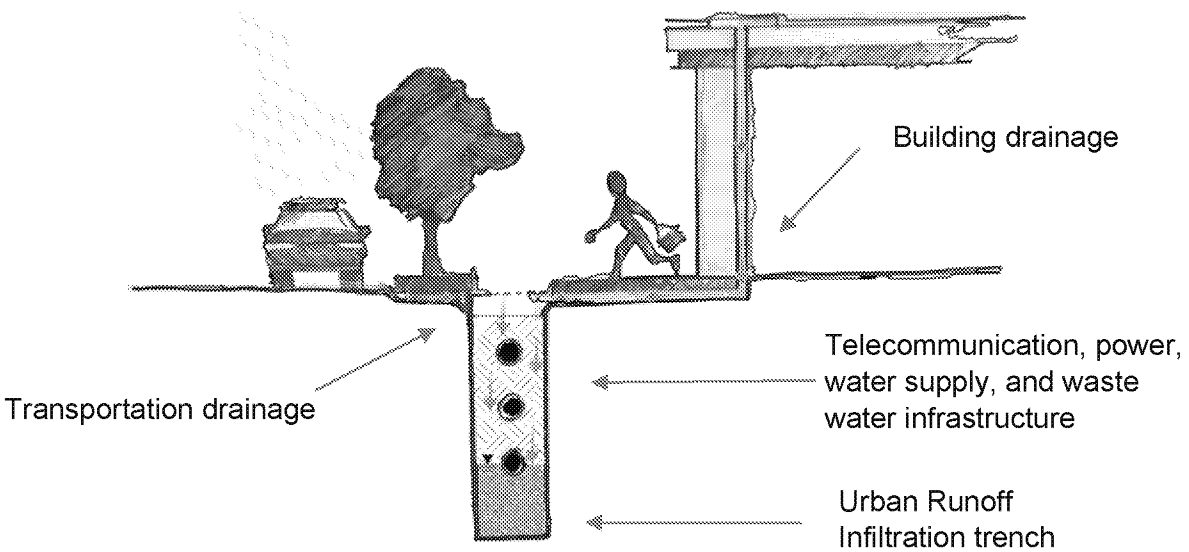

Figure 3: Shared Utility, Transportation, and Building Infrastructure

Agencies and Organizations Involved in Managing Stormwater

Public agencies and professional associations that may lead or advocate for certain projects are described below. This list is meant to be detailed, but not exhaustive. Other agencies, associations, and non-governmental organizations (NGOs) may be valuable partners in increasing capture and use. Many of these organizations have developed resources that specifically support capture and use projects. Links to additional resources identified in this report are found in Section 3.2. Additional information regarding the barriers, drivers, potential projects for statewide solutions, and lead agencies is included in Table 2.

Government Agencies

State Water Resources Control Board and Regional Water Quality Control Boards
The State Water Boards can facilitate capture and use projects by developing and establishing a monetary value of stormwater in volumetric terms as an additional source of local water supply as well as its value to water quality. This aligns with project 1d of the Phase II STORMS stormwater strategy and will assist with the evaluation of multiple-benefit analyses associated with capture and use projects. Along with establishing a value of stormwater, providing guidance for identifying the multiple benefits of projects and linking those benefits with potential funding sources (including local) is essential to implementing stormwater capture and use projects. Streamlining the implementation of capture and use projects would ultimately promote the enhancement, preservation, and restoration of California's water resources for both consumption and environmental purposes. Some barriers and applicable projects that might be addressed by the State Water Board are described in greater detail in Table 2 (See 1 A, 2, 4 A & B, 5 A, 7, 8, 12 A & B, 13 A & B, 14, 16, 18, 21, and 22).

California Department of Water Resources
The Department of Water Resources (DWR) is responsible for managing and protecting California's water resources. In its planning function, DWR provides the state's water plan and IRWM strategic plan, as well as guidance on sustainable groundwater management. DWR evaluates current and future water use and availability, including development of new water supply sources. For example, retrofitting flood control basins provides an ideal opportunity to capture stormwater. DWR can facilitate capture and use projects by developing guidance for evaluation of retrofitting flood control basins for capture and use. In addition, DWR can facilitate the development of statewide requirements and guidance on using a triple bottom line analysis that assesses environmental costs and benefits of various water supply sources using a standardized method. State well standards could also be revised to accommodate capture and use projects by permitting the construction of drywells within drainage areas that may be prone to flooding. DWR is also required to update the Model Water Efficient Landscape Ordinance (MWELO) every three years with the next update effective in 2020. This regulation is composed of minimum standards used in design to create landscapes that more effectively manage stormwater flows by infiltration through healthy soils, interception by plants, and erosion control from the application of mulch and proper grading practices. Some barriers and applicable projects that might be addressed by DWR are described in greater detail in Table 2 (See 8, 10, 13 D, 20, 22).

U.S. Environmental Protection Agency
The Environmental Protection Agency (EPA) has a vital role to play in the implementation of capture and use projects by developing guidance on outreach to communicate a triple bottom line approach that promotes community ownership of water project decisions. The goal of this outreach is to educate and actively engage communities when implementing capture and use projects. The EPA can also assist with the development of funding criteria for multiple-benefit projects that will increase water supply, improve water quality, and provide public health gains. Some barriers and applicable projects that might be addressed by the agency are described in greater detail in Table 2 (See 2, 4 A, 5 B, 16, 17, 23).

California Governor's Office of Planning and Research
The Governor's Office of Planning and Research (OPR) can facilitate the implementation of capture and use projects by developing guidance for stormwater capture and use planning for developers and planners. This guidance can then be adopted into city and county ordinances governing entitlement. Streamlining capture and use projects aligns with OPR's function of coordinating federal grants for environmental goals as well as coordinating the operation of integrated climate adaption and resiliency programs (http://www.opr.ca.gov/about/). Some barriers and applicable projects that might be addressed by OPR are described in greater detail in Table 2 (See 17, 19).

California Natural Resource Agency
Quantifying multiple environmental benefits can be helpful in justifying diverse funding sources. The California Natural Resource Agency can assist with the development of guidance for performing benefits evaluation, including the value of reducing demand for out-of-basin water sources that have associated environmental impacts. In addition to reduced environmental impacts, reduced energy consumption to deliver water should also be acknowledged and considered in the analysis. Early involvement of the agency will promote the protection and responsible management of the state's natural resources. Some barriers and applicable projects that might be addressed by the agency are described in greater detail in Table 2 (See 20).

California Public Utilities Commission
The California Public Utilities Commission (CPUC) oversees investor-owned water supply utilities and serves the public interest by protecting consumers and ensuring the provision of safe, reliable utility service and infrastructure at just and reasonable rates, with a commitment to environmental enhancement. The CPUC can assist with the implementation of capture and use projects by helping quantify the costs associated with a variety of water sources (desalination, recycling, traditional, etc.) from publicly-regulated investor-owned utilities. To efficiently perform a triple bottom line analysis, reductions in energy consumption associated with transporting out-of-basin sources should be considered. Some barriers and applicable projects that might be addressed by this commission are described in Table 2 (See 1 A).

Federal Highway Administration—Office of Planning, Environment, and Realty Research
Transportation projects provide an opportunity to implement capture and use projects within the public right of way. The Federal Highway Administration (FHWA) has an office that is committed to conducting and supporting research that strengthens transportation decision-

making and promotes efficiency while protecting and enhancing our communities and the environment (https://www.fhwa.dot.gov). FHWA can facilitate education and outreach for transportation officials and legislators to incorporate water funding sources into transportation funding. FHWA can help integrate water capture infrastructure within utilities and other infrastructure by providing technical guidance and outreach. Some barriers and applicable projects that might be addressed by the administration are described in greater detail in Table 2 (See 3, 6, 23).

Groundwater Sustainability Agencies

Local agencies are required to submit Groundwater Sustainability Agency (GSA) formation notifications to DWR under the Sustainable Groundwater Management Act (SGMA). The formation of locally-controlled GSAs is required in the State's high and medium priority groundwater basins and subbasins. A GSA is responsible for developing and implementing a groundwater sustainability plan (GSP) to meet the sustainable goal of the basin to ensure that it is operated within its sustainable yield (http://www.water.ca.gov/groundwater/sgm). SGMA may encourage GSAs to implement capture and use projects by fostering stormwater recharge partnerships using MS4 runoff. Some barriers and applicable projects that might be addressed by these organizations are described in Table 2 (See 18, 22).

Municipal Code and Building Departments

Municipal code requires newly developed and redeveloped areas to comply with certain stormwater treatment and infiltration requirements. In California, typically the requirement is to treat runoff from either the one inch, twenty-four hour rain event or the 85th percentile, twenty-four hour rain event. In some areas such as the city of Los Angeles, the trend has been to move towards complete retention of stormwater runoff on-site. This trend promotes increased capture of stormwater that can then be put towards a variety of uses.

Integrated Regional Water Management Groups

Integrated Regional Water Management Groups promote collaboration on a regional scale to identify and implement water management solutions that increase regional self-reliance, reduce conflict, and manage water to achieve social, environmental, and economic objectives. Stormwater planning is a critical component to the Integrated Regional Watershed Management Plans (IRWMP) processes. To improve collaboration among local agencies and nongovernmental organizations throughout a watershed, Stormwater Resource Plans (SWRPs) could be legislatively required. Currently SWRPs are only required for receiving Prop 1 funding. This could push localities to consider how to better utilize stormwater as a resource.

Regional Stormwater Coalitions and Joint Powers Authorities

Regional stormwater coalitions and joint powers authorities (JPAs) promote regional consistency for stormwater management and work to more efficiently manage public resources. The Bay Area Stormwater Management Agencies Association (BASMAA) is an example of a regional stormwater coalition of nine local governments that was formed in response to the NPDES permitting program to promote regional consistency and efficient allocation of resources. JPAs like Monterey One Water and Southern California Coastal Water Research Project (SCCWRP) provide another institutional pathway for regional collaboration and stormwater planning that can evaluate and potentially coordinate the implementation of capture and use projects.

California Department of Fish and Wildlife
Implementing stormwater capture and use projects can result in stream dewatering. The California Department of Fish and Wildlife (CDFW) can provide insight and investigate circumstances where stream dewatering may be a constraint worthy of site-specific analysis. CDFW can develop guidance regarding the scale of projects that would require a study as well as provide a list of additional factors to consider that would trigger the need for further analysis. Early involvement by CDFW in the CEQA process promotes interagency coordination with the goal of minimizing the potential for negative impacts to habitats necessary for the state's diverse fish, wildlife, and plant resources. Some barriers and applicable projects that might be addressed by the department are described in greater detail in Table 2 (See 12 C).

Non-Governmental and Industry Organizations

American Institute of Architects
The American Institute of Architects (AIA) can educate architects about capture and use. Architects need to integrate capture and use into concept plans rather than attempting to find sufficient space for capture and use later in the design process. Some barriers and applicable projects that might be addressed by these groups are described in greater detail in Table 2 (See 4 A).

American Association of State Highway Transportation Officials
Roadway infrastructure can be challenging to integrate with stormwater infrastructure. The American Association of State Highway Transportation Officials (AASHTO) can work to educate the public and key decision makers about the role transportation projects can play in capture and use projects. AASHTO can also lead education and outreach to transportation officials and legislators to incorporate water infrastructure and water funding sources into transportation funding. This educational outreach is essential to streamlining the implementation of multiple-benefit capture and use projects. Some barriers and applicable projects that might be addressed by these groups are described in greater detail in Table 2 (See 3, 6).

American Planning Association
The American Planning Association (APA) advocates for "excellence in planning, promoting education and citizen empowerment, and providing its members with the tools and support necessary to meet the challenges of growth and change." APA can provide guidance for stormwater capture and use planning to developers and municipal planners, which can be adopted into city and county ordinances. The association could also provide education and outreach about integrating water capture infrastructure into transportation projects. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 17, 19).

American Public Works Association
The American Public Works Association (APWA) serves professionals from local, county, state, federal, and private sector backgrounds who work in all aspects of public works projects focused on positively impacting the quality of life in the communities they serve (http://www.apwa.net). APWA has been a leader in the development of guidance on identification of the multiple benefits associated with projects via the Envision™ program. As such, APWA is well suited to continue to help advocate and train in the use of a triple bottom

line approach that will ultimately increase community ownership of water project decisions. Some barriers and applicable projects that might be addressed by the association are described in greater detail in Table 2 (See 1 B, 4 A, 5 B, 10, 16, 19, 23).

American Rainwater Catchment Systems Association
Storing water for extended periods of time can impose a barrier to capture and use projects, particularly when oxygen levels decrease, requiring additional treatment costs. The American Rainwater Catchment Systems Association (ARCSA) is committed to promoting the advancement of rainwater collection and could provide guidance for storage of captured water for irrigation and identification of innovative technologies to expand storage times. In addition, the association could assist local departments of public health in applying appropriate requirements associated with using captured stormwater. Some barriers and applicable projects that might be addressed by this association are described in greater detail in Table 2 (See 9, 21).

American Society of Civil Engineers
Technical guidance regarding the implementation of capture and use systems is needed. The American Society of Civil Engineers (ASCE) and its Environmental and Water Resources Institute (EWRI) focuses on advancing water resources and environmental solutions to achieve a sustainable future (http://www.asce.org/environmental-and-water-resources-engineering/environmental-and-water-resources-institute/). ASCE can lead projects to develop technical guidance on capture and use projects that ultimately align with the organization's efforts to support sustainable infrastructure and technologies. Some barriers and applicable projects that might be addressed by these groups are described in greater detail in Table 2 (See 4 A, 21).

American Water Works Association
The American Water Works Association (AWWA) is an international nonprofit, scientific, and educational society dedicated to providing total water solutions aimed at assuring the effective management of water. AWWA offers education to water professionals and is an advocate for safe and sustainable water. For more than 100 years the association has developed technical standards for minimum requirements, materials, and equipment and practices used in water treatment supply (https://www.awwa.org/publications). AWWA may also be suited to identify innovative technologies to expand storage times. Some barriers and applicable projects that might be addressed by this group are described in greater detail in Table 2 (See 9, 14, 16, 21).

Association of California Water Agencies
The Association of California Water Agencies (ACWA) is the largest statewide coalition of public water agencies in the country. The mission of the agency is to help members promote the development, management, and use of good quality water at the lowest practical cost and in an environmentally responsible manner. ACWA can facilitate the implementation of capture and use projects by developing a standard method for valuing captured stormwater that could be applied throughout the state. Some barriers and applicable projects that might be addressed by this association are described in Table 2 (See 1 A).

California Stormwater Quality Association
The California Stormwater Quality Association (CASQA) is an organization that can leverage expertise throughout the stormwater sector by addressing stormwater issues within the subcommittees of the association. These subcommittees can develop problem statements and advocate for funding. CASQA can also collaborate with a number of agencies and organizations to promote capture and use projects. For example, CASQA can coordinate with the Governor's Office for Planning and Research to develop guidance for stormwater capture and use planning for developers and municipal planners to be adopted into city and county ordinances governing entitlement. CASQA can also work with the State Water Board and DWR to provide training to better understand natural hydrologic and hydrogeomorphic processes associated with drywells. These projects all align with the association's vision to advance stormwater quality management through collaboration, education, and implementation guidance. Some barriers and applicable projects that might be addressed by this association are described in Table 2 (See 7, 13 C, 16, 17).

Local Government Commission
The local Government Commission (LGC) has published Ahwahnee Water Principles that outlines stewardship actions that cities and counties can take to reduce costs and improve the reliability and quality of water resources. These principles include incorporating water holding areas such as creek beds, ponds, and cisterns into urban landscapes as well as designing landscapes to reduce water demand, retain runoff, decrease flooding, and recharge groundwater. Additional information can be found via the Urban Stormwater Management Fact Sheet. The LGC also educates decision makers about opportunities for stormwater capture and use. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 5).

National Association of City Transportation Officials
The National Association of City Transportation Officials (NACTO) is focused on providing transportation options that are safe, sustainable and accessible. The association provides an Urban Street Stormwater Guide that offers guidance for municipalities to incorporate sustainable stormwater management practices to support ecosystems with human land use and development. NACTO is focusing on integrating green stormwater infrastructure into the right-of-way, which requires a holistic vision for sustainable urban design (https://nacto.org). The association can continue to educate city transportation officials regarding stormwater management and capture as well as opportunities to implement capture and use projects. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 3, 6).

National Association of Flood and Stormwater Management Agencies
The National Association of Flood and Stormwater Management Agencies (NAFSMA) is an organization of public agencies whose mission is to encourage technologies and conduct education programs that facilitate and enhance the achievement of the public service functions of its members. This organization appears to provide an ideal link between stormwater and flood control agencies. NAFSMA could collaborate with stormwater and flood control agencies to develop guidance for evaluation and design of retrofitting flood control basins for capture and use. Some barriers and applicable projects that might be addressed by this association are described in greater detail in Table 2 (See 8).

National Blue Ribbon Commission for Onsite Non-Potable Water Systems
To assist local departments of public health in applying appropriate requirements associated with using captured stormwater, treatment requirements that do not require Title 22 could be adopted for all captured stormwater exclusively using existing, unused purple pipe (no comingling with recycled water). The National Blue Ribbon Commission for Onsite Non-Potable Water Systems could assist with the adoption of these requirements that would streamline the implementation of capture and use projects and align with the commission's mission of advancing best management systems to support the use of onsite non-potable water systems within individual buildings or at the local scale. Some barriers and applicable projects that might be addressed by this commission are described in Table 2 (See 14).

National Municipal Stormwater Alliance
The National Municipal Stormwater Alliance (NMSA) vision statement focuses on enabling MS4 permittees across the country to develop efficient and effective stormwater programs. As a national organization representing many MS4 programs, NMSA can help promote federal guidance and regulations that provide incentives (or remove disincentives) to capture and use. NMSA can also help with public education and outreach as well as collaborate with FHWA on education and outreach programs to transportation officials and legislators to incorporate water infrastructure into transportation funding. Some barriers and applicable projects that might be addressed by the organization are described in greater detail in Table 2 (See 1 B, 3, 6, 8, 21).

Transportation Research Board, Standing Committees on Stormwater and Landscape and Environmental Design
The Transportation Research Board (TRB) has several committees that could provide valuable education and outreach to transportation officials and legislators to incorporate water infrastructure and water funding sources into transportation funding. The Standing Committee on Stormwater is concerned with the design and construction of transportation-related stormwater facilities to address runoff of pollutants, methods for managing stormwater volume and flow, and methods for improving water supply and stormwater quality (https://map08g.wixsite.com/afb65). The Standing Committee on Landscape and Environmental Design is concerned with design parameters that relate to protecting, conserving, restoring, and enhancing safe, sustainable, and livable transportation systems and facilities and their associated environments (https://sites.google.com/site/trbcommitteeafb40). Some barriers and applicable projects that might be addressed by these committees are described in greater detail in Table 2 (See 3, 6).

Urban Land Institute
The Urban Land Institute (ULI) provides leadership in the responsible use of land and in creating and sustaining thriving communities worldwide (https://uli.org/). ULI can help facilitate capture and use projects by assisting with the development of approaches for valuing stormwater as a resource and outreach associated with educating the public that enhanced water management mechanisms create value by enhancing aesthetics and improving operational efficiency. Some barriers and applicable projects that might be addressed by this organization are described in Table 2 (See 17).

Water Environment Federation/Stormwater Institute
The Water Environment Federation (WEF) and its members have protected public health and the environment since its establishment in 1928. WEF has a diverse membership including scientists, engineers, regulators, academics, utility managers, and other professionals who share the common goal of improving water quality. WEF has developed an initiative for National Stormwater Testing and Evaluation for Products and Practices (STEPP) (http://stormwater.wef.org). This program aims to fill the void created by a lack of national stormwater control measure testing and verification programs. The STEPP process may be adapted to address capture and use verification. Some barriers and applicable projects that might be addressed by this federation are described in greater detail in Table 2 (See 4 A, 21).

Water Environment and Reuse Foundation
The Water Environment and Reuse Foundation (WERF) is a nonprofit that conducts research to treat and recover beneficial materials from wastewater, stormwater, and seawater including water, nutrients, energy, and biosolids (http://www.werf.org). WERF has sponsored projects that are beneficial to capture and use by developing a "First Steps" spreadsheet-based tool to help utilities evaluate the costs and benefits of diversifying their overall water management portfolio. Additional projects led by the foundation include an effort to assess the risks, costs, and benefits of using stormwater to enhance local water supplies. This analysis includes identifying co-benefits and performing a triple bottom line analysis. A life-cycle cost analysis tool was developed as a part of this project to guide decision makers in the selection of stormwater infrastructure alternatives. WERF can continue to advocate for capture and use projects by developing other tools to assist decision makers and raise awareness regarding capture and use opportunities. Some barriers and applicable projects that might be addressed by this foundation are described in greater detail in Table 2 (See 4 A, 21).

Water Foundation
The Water Foundation is focused on enabling new and innovative approaches to meet collective water needs. The Foundation has been an advocate for SB 231, which would allow local governments to levy taxes for purposes of stormwater management projects. One of the foundation's goals is to pool and align philanthropic funding to support groups that are finding smart ways to improve water management. Building bridges among diverse leaders and catalyzing partnerships to develop and implement projects while helping shape collaborations into lasting networks would be beneficial for capture and use projects. Some barriers and applicable projects that might be addressed by this foundation are described in Table 2 (See 7).

2.4 Building Coalitions at the Municipal Scale

The WEF 2015 Green Infrastructure report identified the variety of stakeholders that should be considered for engagement in community-based stormwater systems planning. These stakeholders are listed in Table 1 and should also be considered for capture and use implementation.

Table 1: Community Stakeholder Engagement

Stakeholders for Engagement in Green Infrastructure Program	
Sewer Council/Commissioners	City Council (as applicable)
City/Municipality Planning Department	County Planning Department (as applicable)
Health Department	Local foundations, grant agencies, etc.
Department of Public Property	Streets Department
Mayor's Office	City Public Works
Drinking Water Utility	City Parks Department
City/County Roads Department	State Department of Transportation
Telecom, Transit, Gas and Electric Utilities	Local universities
Economic Development Council/Agency	Local developers
Regional Coordination/Planning Agencies (as applicable)	Regional Transportation Planning Agencies
Local Environmental Groups	Local EPA or Department of Environmental Protection
Local watershed/waterkeeper/conservation groups	Experts from local and national consultants
Local development engineers/architects	Local School Boards
Urban Development/Housing Authority	Local landscapers and arborists
Local businesses/retail owners	Members of the general public not directly involved with water issues

3 Capture and Use Tools

The appropriate tools for implementing capture and use necessarily depend on the definition of capture and use. The next section offers a definition, followed by an introduction to the tools.

3.1 Defining Capture and Use

To date, capture and use has been focused on enhancing water supply through either capture and storage in tanks for direct use or recharge of aquifers (NAS 2016). But this report outlines a broader definition. Because the State Water Board aims to support valuing stormwater as a resource and to encourage active capture of urban runoff, a definition of urban runoff capture and use was developed: the intentional collection of urban runoff to augment surface water supplies, to recharge groundwater, or to support ecosystems. This new, broader definition requires additional explanation.

"Intentional collection" is used to differentiate intended actions to enhance use of runoff from other passive approaches. For instance, intentional actions may include infiltration basins or green streets that capture and recharge stormwater, while passive approaches include preserving open space to maintain natural hydrologic function. While laudable, these passive approaches do not change the urban runoff water balance to increase the use of stormwater. Intentional collection requires infrastructure to increase capture and use in both retrofit of existing and building of future urban development.

The term "urban runoff" is used because it includes both urban stormwater and urban dry weather flows, and both have been undervalued resources. Dry and wet weather runoff also share common barriers and they often benefit from the same capture and use infrastructure.

> **Definition: Capture and Use**
>
> The intentional collection of urban runoff to augment surface water supplies, to recharge groundwater, or to support ecosystems.

Capture and use encompasses at least one of three actions: augmenting surface water supply, recharging groundwater, or supporting ecosystems.

To augment surface water supplies—Surface water supplies are typically managed through controlled infrastructure at many scales, from rain barrels to statewide distribution systems. The collected water is used to satisfy a variety of water demands, such as indoor and outdoor non-potable, potable, industrial, and agricultural. Capture and use can augment these supplies by direct injection or in lieu augmentation where some of the water demand is offset by separate stormwater surface water systems (e.g., rain barrels). Where LID is used in place of planned landscaping, the amount of urban runoff used by vegetation in lieu of other irrigation water supply could also be considered an in lieu augmentation of surface water supplies. The term "surface" is used to distinguish these supplies from aquifer supplies, so, for example, a subsurface cistern would still be considered a surface water supply system. Use of urban runoff is consistent with the goals of the California Water Plan, which endorses stormwater as a water supply source that could improve supply reliability (DWR 2013).

To recharge groundwater—Recharging groundwater promotes the movement of runoff to aquifers for reasons including, but not limited to, preventing seawater intrusion and subsidence, fortifying supply, and sustaining surface water habitats. Groundwater recharge can support surface water habitats by maintaining baseflow to surface waters. In this way, groundwater recharge can also support ecosystems.

To support ecosystems—Capture and use can support ecosystem functions and help maintain and restore stream, wetland, and estuary habitats for species of management concern. The role of capture and use for ecosystem support is best achieved through a watershed approach that recognizes the importance of water and sediment movement, infiltration, and groundwater recharge and discharge for supporting ecosystem processes and habitat. The state legislature affirmed the importance of watersheds in providing clean water in AB 2480, which recognizes watersheds as part of the California water system. Post-construction standards in some regions also embrace the premise of preserving or restoring existing watershed processes (Central Coast Regional Water Board 2013). Achieving these goals can be challenging in watersheds that have been altered by urban or agricultural land uses. In these cases, the concept of "environmental flows" can provide an approach to balance potentially competing goals for managing runoff. Environmental flows are defined as "the magnitude, timing, duration, rate of change, and frequency of flows and associated water levels necessary to sustain the biological composition, ecological function, and habitat processes within a water body and its margins" (Brisbane Declaration, modified by The Nature Conservancy). This definition focuses on replicating key aspects of the annual hydrograph that are critical to support desired ecological goals, rather than restoring "natural hydrology." Capture and use can be an integral tool for managing environmental flows and replicating key hydrograph features to the benefit of ecosystems (NRC 2008; Walsh and Kunapo 2009). In addition to managing environmental flows, capture and use strategies can support ecosystems by improving water quality through the reduction of pollutant loading to streams and estuaries (Lager and Smith 1974; Tourbier and Westmacott 1981; NURP 1983; Schueler 1987).

The stormwater capture and use definition should not discriminate against stormwater projects based on scale or treatment approach. For example, projects that divert stormwater to the headworks of reclamation plants should be counted as capture and use projects where reclaimed water is put to one of the uses described above. This is also consistent with the One Water philosophy.

Capture and use also supports clean surface water by diversion or sequestration of pollutant loads associated with the captured volume. Runoff volume reduction practices have been widely recognized as a water quality tool (Lager and Smith 1974; Tourbier and Westmacott 1981; NURP 1983; Schueler 1987). These and other benefits of particular capture and use approaches are discussed in Appendix A.

3.2 Tools and Resources

Delivering capture and use infrastructure requires use of structural and non-structural tools. Structural tools include stationary and permanent BMPs that are designed, constructed, and operated to prevent or reduce the discharge of stormwater pollutants and/or prevent or reduce the impact of peak runoff flows.

Structural Tools

Structural stormwater water control measures (SCMs) can be grouped according to scale. Centralized systems typically capture runoff from multiple parcels and decentralized systems typically capture runoff within a single parcel (MWD 2015). SCMs that can be applied at both the parcel level and at a larger neighborhood scale are listed below as both centralized and decentralized. The types, use potential, potential benefits, and factors affecting success are summarized in Appendix A.

- Structural stormwater control measures (SCMs)
  - Centralized (difficult to scale down)
    - Detention Basin (lined and connected to regional use)
    - Detention Basins (unlined for infiltration)
    - Detention Basins with Drywells
    - High-Flow Bypass to Spreading Grounds
    - Wet Basins
  - Centralized/Decentralized (highly scalable)
    - Detention Vault/Cistern (lined for local use)
    - Infiltration Vaults (infiltrators)
    - Infiltration Basins (retention basins)
  - Decentralized (difficult or expensive to scale up)
    - Infiltration Trenches
    - Bed Filter with Infiltrating Underdrain
    - Bioretention Raingarden (underdrain)
    - Bioretention Raingarden (no underdrain)
    - Green Roofs
    - Pervious Pavement
    - Swales, Filter Strips (biofiltration, buffer strips)

Non-structural Tools

Non-structural tools are just as vital to implementing capture and use as the SCMs themselves. The non-structural tools listed below are grouped by valuation, regulation, incentive programs, fiscal, and institutional. Some of these types of tools are interdependent (e.g., funding is required for incentive programs). Also, some tools are not supported by surveyed case studies and literature (e.g., requiring retrofit of private property). The availability or examples of usage of non-structural tools are summarized in Appendix A.

- Non-Structural tools
  - Valuation
    - Cost
    - Support ecosystem function
    - Triple bottom line (economic, environmental, and social valuation)
  - Regulation of Private Property

        - Performance standards for new construction and redevelopment (requiring stormwater controls that reflect regional needs such as hydromodification or groundwater deficit)
        - Retrofit requirements on existing developed properties
    - Regulation and Local Policy Governing Public Property
        - General plan requirements to assess local water supply feasibility (including urban runoff)
        - New and redevelopment of public infrastructure (requirement for stormwater controls that reflect regional capture and use needs)
        - Retrofit program for existing public development with stormwater controls that reflect regional capture and use needs
        - Requirements regarding growth type, such as density, infill, and zoning, that consider local and regional water resources and needs.
        - Policy of agency coordination, leveraging funds/projects to overcome financial barriers (e.g., transportation, parks, and economic development)
    - Incentive Programs
        - Voluntary Offset Program: Property owners place a bid for stormwater capture and use projects to be installed on their property for free, and an amount of money for which they would like to be compensated for accepting these projects on their property. The bids are weighted according to the cost of the project and the amount of environmental benefit it will provide. The bids are ranked according to least cost and largest environmental good. The bids are awarded until the money available is expended.
        - Fast Track Review: Provides a faster permit review process for projects that have incorporated capture and use
    - Fiscal
        - Grants for capture and use projects with options for long-term O&M
        - Grants for technical consultation, evaluation, and capacity building/finance planning
        - Triple bottom line guidance for both water and non-water agencies to assess benefits of supporting stormwater capture and use
        - Assessment guidance on marginal cost of capture and use vs. treatment and release
    - Institutional
        - Joint Powers Authority (JPA) or Enhanced Infrastructure Financing Districts (EIFDs)

Resources for Capture and Use

In addition to the government agencies and professional organizations listed in Section 2.3, there are a number of organizations that provide resources that may be helpful in public engagement, design, alternatives analysis, benefits quantification, and other aspects of implementing capture and use. The following list includes agency names as well as links to those resources that may assist with advocating for and implementing capture and use projects.